Open BIM Adoption in Sri Lankan Construction Industry

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Abstract

Open Building Information Modelling (openBIM) deviates from conventional approach while impacting whole Architecture, Engineering, Construction and Operations (AECO) industry. A basic outcome of openBIM is the collaboration by different project partners at different construction stages of the whole life cycle of the project without interoperability issues. The openBIM is based on the Industry Foundation Classes (IFC) data model standards and BIM Collaboration Format (BCF) is used for supporting data model standards. The latest mode of sustaining operability with actors utilizing products of numerous corporations is endowment of openBIM servers by means of plural data environments. Several supporting applications which required to exchange integrate data thus results in the requirement of an open standard and it is further notified in plural data environment. The openBIM practical application provides continues information flow throughout all projects participants in whole life cycle of a construction. Even though openBIM provides wide variety of advantages, there are some challengers which will arise when adopting new framework for a work environment. Different organizations will have their own policy about tool usage, budgeting requirements, licensing restriction, etc. which will come in the way of adopting different technology. Henceforth, the study aims to identify the potentials for adopting openBIM in Sri Lankan construction industry.

Mixed method approach was adhered for the research conduct. Data collection was processed where data sources were selected based on contribution for the BIM and openBIM in AEC industry. A questionnaire survey was conducted among construction industry experts who were familiar with construction related software applications and was conducted via iBIM LK Survey tool. In-depth data analysis of the collected data throughout the questionnaire survey were clearly analyzed in both quantitative and qualitative methods separately and made clear cross reference between them. The quantitative section was analyzed through the exploratory quantitative analysis method and qualitative section through the manual content analysis method. Thus, it was identified that potential for its adoption is very low in current context of Sri Lanka and key challenges are identified in technical and industrial perspectives. Accordingly, technical challengers were associated with high cost to build-up IT infrastructure for required level, low level of awareness of open source software and lack of training facility. The industrial challenges were identified as resistance to change, lack of openBIM based projects, legal system not fully cooperated with contractual agreements in openBIM, requirement of an openBIM project governing regulatory body and systematic protocol for proper openBM adoption in Sri Lanka. Hence, it highlights the requirement of enhancing knowledge of professional practitioners on openBIM. Moreover, it is prerequisite to amalgamate systematic protocol for openBIM based projects and government's initiation is essential for the adoption of BIM. Government responsibility for openBIM implementation in Sri Lanka may be appropriate remedy for storage of openBIM project.

Keywords: Open Building Information Modelling (openBIM), Adoption, Interoperability, Open standards, Free and Open Source Software (FOSS)

1. Introduction

The construction industry is rapidly enlarging globally. The modern construction projects are getting dynamic and complex while encouraging massive time overruns, construction waste, poor quality outputs and blunders which undoubtedly amplify the construction cost. The construction is considered to be an information concentrated industry where different type of data is transferring from inception to demolition of a facility. Thus, there is a greater essentiality to build up a common platform for construction project management to exaggerate the efficiency and effectiveness of construction project outcome. Consequently, the Building Information Modelling (BIM) has become a greater revolutionary paradigm within construction

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context to assist in making a common working platform for every stakeholder within a construction project. According to Motawa and Almarshad (2013), BIM is improving the productivity, efficiency, value, quality, and sustainability while reducing the lifecycle costs, lead times and duplications through effective collaboration and communication of stakeholders in construction projects. However, BIM has an interoperability issue between Architecture, Engineering, Construction and Operation (AECO) industries software (Excellence, 2012). As per Blog (2017), interoperability was explained as capability of different software to exchange data via a common set of exchange formats. In order to build up the interoperability within BIM environment, Autodesk has developed a cloud supported integrated service as Industry Alliance of Interoperability (IAI) in 1994. In 2005, this IAI was changed to buildingSMART and currently it is prevalent international organization which enhance the information exchange between software used in the construction industry.

Consequently, buildingSMART has developed a universal approach known as 'openBIM' which permits project stakeholders to contribute in BIM irrespective of the software tools they use. Accordingly, Industry Foundation Classes (IFC) are the international standard for BIM which acts as an open and neutral data format for openBIM (Nisbet & Liebich, 2007). They enable to share and exchange construction and operational data across different software applications. Basically, openBIM enables to maintain the title and the obligation of each participant of the project (BIMhub, 2017). Even though openBIM provides wide array of advantages, there are some challengers which arise when adopting new framework for work environment (Panuwatwanich, Wong, Doh, Stewart, & McCarthy, 2013).

Different organizations have their own policy about tool usage, budgeting requirements, and licensing restrictions which will challenge the way of adopting BIM (Zhi, 1995). Furthermore, the technology itself may generate barriers in integrating because of difference in user experience, available task set, and some closed data models may provide specific functionalities which are not available as part of the openBIM standards (Building Smart Standards, 2008). The scenario can be analogously analysed comparing popular operating systems Windows and Linux. Even though, Linux provides open system, majority of the general population prefers Windows due to personal reasons and the inertia to make a move from the comfort zone (Hallberg & Tarandi, 2011). From a corporate perspective, different organizations have different attitude about the usage of operating systems (Rousset, 2008). Accordingly, some prefer Windows because it provides complete set of organizational management solution for users. Linux might provide better usability for the actual users on their task having tight control over the file system and architecture (Economides & Katsamakas, 2006). These kinds of challenges will present during the period of diffusion of any different technology and those have to be analysed and investigated to overcome those efficiently in order to expand the usage of openBIM systems in building construction sector (Hallberg & Tarandi, 2011).

Sri Lankan construction industry is a blooming industry (Bank, 2015) which passes its infant stage in adopting BIM (Jayasena & Weddikkara, 2012). Therefore, openBIM is novel concept to Sri Lankan construction Information Technology (IT) architecture. Henceforth, this study aims to identify the adoptability issues and technological solutions of applying openBIM in Sri Lankan construction industry.

2. Literature Review

2.1. Sri Lankan Construction Industry and Its Current Information Handling Status

The Sri Lankan construction industry has a hasty enlargement from 2009 including extreme amplification in infrastructure and reconstruction projects (Central Bank, 2009). Accordingly, construction industry reached to 8% of country's Gross Domestic Product (GDP). Thus, most of the foreign construction firms have exposed their willingness to invest in Sri Lankan construction industry. Due to the high complexity and rapid development in the industry, there is an essentiality to have a common data platform to exchange data among project stakeholders (Nitithamyong & Skibniewski, 2004). Furthermore, Jelle (2013) explicated that all the stakeholders should stick together for a short period of time to yield a more efficient project. However, in Sri Lankan context this has become a miracle and most of the practitioners are still searching a best way to overwhelm the aforementioned complications.

According to Weerasinghe and Ekanayake (2012), Sri Lankan construction industry is extremely retarded in adopting a new technology. Henceforth, the industry is still using the paper documentation not yet fully utilize the Information Technology (IT) in planning and execution process. AECO industries commonly use paper as the medium for exchange information and data between the project participants. However, inadequate interoperability of this conventional method rises the construction cost and inefficiencies in final output. These interoperability issues disturb the diffusion of automated AECO industry practices (Gallaher, O'Conor, Dettbarn, & Gilday, 2004). In addition, Yang and Zhang (2006) stated that designing a building is an extremely collaborative process which use heterogeneous computer-support systems. Such design environments cause the interoperability issues. There are various types of interoperability issues which were categorized according to the degrees of interoperability. This categorization is based on the probability of data of a software being accepted in another software.

2.2. Building Information Modelling (BIM)

BIM can be introduced as a solution for the data and information exchange issues between project participants. BIM provides a common data environment for all the participants to exchange their data and express their ideas (Merschbrock, 2014). According to National BIM Standards (2016), BIM is a digital representation of physical and functional characteristics of a facility. Further, it is a shared knowledge resource for information about a facility, forming a reliable basis for decisions making during its lifecycle. Moreover, Aia (2017) expounded that, BIM is a modern technology which provides a common digital data environment for collaborating and sharing information throughout all the contributors of the construction project. According to Eastman et al. (2008), the success of a project does not wholly depend on the BIM adoption. Further to them, BIM is only a supporting technology for working team of the project, management team and cooperate owners to make the project a successful. However, BIM cannot replace a good management team or good cultured workers. Subsequently Eastman et al. (2008) highlighted that BIM adoption is beneficial for a typical construction project in terms of technically, contractually and socially.

Generally, there should be a certain standard for technology usage where every user of the technology can make the same degree of success or failure. Similarly, BIM also wants a support of a common format for data exchange; by which all the project participants may not face any interoperability issues (BIM Blog, 2017). According to Hijazi (2015), interoperability in BIM means the proficiency of diverse programmes to interchange data through a common set of exchange formats. Azam and Hussain (2009) exposed that it is easy to change to a different software platform rather than moving to a whole different software package. However, in AECO industries it is difficult to adopt because different firms use diverse software systems for their variety of job tasks. Therefore, the best way to maintain interoperability is to pace forward to a common platform.

Accordingly, the Autodesk® software developing company realized the need of an advance information exchanging tool in an open format for modern BIM enabled construction projects. Consequently, they introduced Autodesk Green Building Studio (GBS) which was latterly not successful as expected. After the failure of GBS, Autodesk further developed file converter applications to convert files from one format to another transformable format. This file converting capability implemented by installing software plug-in to existing software. This software plug-ins are based on Microsoft Visual C++ coding language. These plug-ins overcome the material data confusion and geometric misrepresentation while solving the existing file interoperability issues to some extent (Guzmán & Zhu, 2014). However, to overwhelm the issue completely, the requirement of a standard information and data exchange seriously evolved with the time. In this situation, IAI gave a significant contribution for making a common data exchanging language which was latter known as buildingSMART. IAI was considered as a worldwide collaboration of industry professionals, software developers and researchers for overcome interoperability issues and develop them (Froese, 2003). IAI organizations' primary task was producing interoperable file format for all type of software users in AECO industry. Subsequently, they produced Industry IFC as the interoperable file format (Liebich & Wix, 1999).

2.3. What is openBIM?

According to buildingSMART (2018), "openBIM is a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows". Further to them, it supports an open workflow by creating a common language for extensively referenced processes and allows project stakeholders to participate regardless of the software tools they use. Bestowing to Azam and Hussain (2009), there is a difference between "openBIM" and "OPEN BIM". Further to authors, OPEN BIM is a software development method for development of BIM software while openBIM is a concept which developed to exchange data between stakeholders of AECO industry and between different software platforms.

2.4. Open Software Frameworks and Standards

Basically, BIM is based on many frameworks which are specifically developed to generate separate service to BIM adoption (Breit et al., 2008). One of such frameworks in openBIM systems is interpretability framework developed by buildingSMART which provides the collaboration and data sharing capabilities of an openBIM system (Hijazi, 2015). Furthermore, Level of Development (LOD) framework launched in 2008 with the AIA E202 document provide a better team working environment for BIM adoption (McGraw Hill Construction, 2012). Moreover, the modern BIM adoption is subjected to management framework which consists the management mental processes helpful for designers in design stage and facilities managers in operation stage (Hassanain, Froese & Vanier, 2001). Additionally, BIM business drivers also have separate framework to provide service in BIM system. This framework facilitates at the beginning of the project and it can identify property owner, engineer and contractor and their respective priorities. Besides, legal framework provides a clear allocation of resources, responsibilities and duties of a BIM team (Breit et al., 2008). Economic analysis framework is another important framework which is a combination of technical, economics and cash flow aspects to make estimates through BIM (Gallaher et al., 2004). Lastly, combination of all these frameworks provides a better BIM system for whole AECO industry to be more effective and efficient.

In addition to frameworks, there are some open software standards which should be followed for a successful BIM adoption. Accordingly, CIMSteel Integration Standards (CIS/2) is established to enable a more united method of working via data sharing and management within companies involved in steel framed buildings construction (Lipman, 2011). Furthermore, there are many ISO (International Organization for Standardization) standard related to BIM (Hill & Steele, 2014). According to Cerovsek (2011), ISO standards can be elaborate by 3C-s; competitiveness, conformity and connectivity. These three main tools help to make a standard for innovation. International Framework for Dictionaries (IFD) is another standard which is developed by buildingSMART. Here, data dictionaries are major components of openBIM concept and this buildingSMART Data Dictionary (bSDD) is considered as the reference library for IFDs. IFD helps to develop interpretability among the software of the AECO industry (Jayasena, 2015). IFC is a significant standard for data exchange function in BIM. IFC data model consists of geometry and properties of "intelligent" building components and their connections to the other components of the building projects (Autodesk, 2016). According to Van den Helm, Böhms and van Berlo (2010), IFC is a natural data model based on development of construction industry. IFC facilitates to share information between software applications and stakeholders of AECO industry. In addition, it provides additional facilities such as determination of the hierarchy of the building elements. Moreover, IFC has unique capability to develop a new version based on the existing versions and it is considered as the most stable data exchanging standard in the ACEO industry (Froese, 2003). Lastly, Standard for the Exchange of Product also known as STEP is an international standard which is capable of distributing project data independently with most of systems. This is an ISO 10303 version, and this can be used in whole lifecycle of a project. STEP supports to develop all project data quality in Computer Aid Designing (CAD) systems (Aia, 2017).

2.5. Challenges for openBIM Implementation

OpenBIM is a novel concept for most of the countries in the world. Thus, there are lot of technical challenges which inhibit the openBIM adoption within a BIM enabled construction industry. Confirming, Juan and Zheng (2014)

explicate that, most of the openBIM service providers are not using cloud-based technologies which provide a good security and reliability for building information. Furthermore, Construction Operation Building Information Exchange (COBie) data standard which is used for openBIM has data drops during the data transition process (Blog, 2017). Moreover, Hallberg and Tarandi (2011) stressed that in last five years' time Autodesk Revit release more than fifty IFC updates which is a tedious aspect in perspective of users.

According to Hijazi (2015), not only the technical challenges but also the industrial challenges barricade the successful adoption of openBIM. Graphicsoft (2013) clearly highlighted that different stakeholders expect diverse requirements from an openBIM adoption. Accordingly, there are 13 requirements of software venders, 10 requirements from AECO organizations and 4 requirements from construction project stakeholders. Further to them, all these requirements should be fulfilled to yield maximum productivity of an openBIM system. Thus, there are industrial challengers which should be overwhelmed for a successful openBIM adoption.

Additionally, there are some other challengers which impact the openBIM adoption especially when moving from native format to open format. Generally, proprietary software use their own native exporting format which are not interoperable with other software used by project partners (Bergeron & Allott Moore, 2011). Contrariwise, non-proprietary file formats can be read and write by any type of software (Huovila, Hyvärinen, & Palos, 2014). IFC and COBie are the main non-proprietary software. When moving to these open formats from native format, huge amount of data losses especially during exporting (Huovila et al., 2014). Thus, it is a challenging aspect to be considered.

2.6. Open Source Software Support in Sri Lanka

In Sri Lanka, there are two types of Free and Open Source Software (FOSS) providers. There is one category of software which can be downloaded free of charge and only have a community support. On the other hand, there are software which can be downloaded free of charge and customer can purchase vender support if he requires. There are so many predominant100% open source software companies in Sri Lanka and they develop open source software and sell them with or without vender support (WSO2 Cooperation, 2017). Further, the community support open source software provides online forums as a common platform for open source software users. However, all these open source software have encountered number of problems and lapses (Exchange, 2017).

Sri Lanka needs open source software when considering all the social, economic and technical factors (Elvitigala, 2002). Even if the modern construction industry is in kindergarten stage of BIM adoption, it heavily uses computer applications to improve the productivity and to reach lean objectives. According to Aruna, Perera and Weerawarne (2013), open source software solutions have more positive marks in Sri Lankan context. Thus, it is essential requisite to investigate on factors for successful adoption of openBIM in Sri Lanka.

3. Research Methodology

Research methodology is the whole procedure which conducts to fulfil the research aim extending from the theoretical foundation to collection and analysis of data (Fellows & Liu, 2008). Firstly, an extensive literature review was conducted to build up the foundation for the research. Through the literature synthesis insight to BIM, openBIM and common challenges to adopt openBIM were identifying extensively. Subsequently, the mixed research approach was used for the study by combining both quantitative and qualitative approaches to diminish flaws and glitches associated with mono approaches (Teddlie & Tashakkori 2003; Johnson & Onwuegbuzie 2004; Neuman, 2011). Further to them, it improves the validity and reliability of results while enhancing the comprehension of study directing to novel dimensions. Basically, the research considered on the IT skills and computer literacy of the AECO industry stakeholders. Since, there is limited number of practitioners with in Sri Lankan context who have adequate knowledge on BIM and its applications, the research was wholly conducted based on an exploratory nature. The online questionnaire was prepared in 'iBIM survey' website which was linked to iBIM.lk. The website offers survey facilities for BIM related research while providing proper research background and knowledge of BIM to academicians.

Consequently, the gathered qualitative data was analysed using content analysis which is widely used qualitative analysis technique. According to Westbrook (1994), the content analysis generates logical and reliable implications from the collected data while becoming the most applicable technique to adsorb, summarize and define the content included. Subsequently, the quantitative data was analysed from iBIM survey research facility from which the online questionnaire was also prepared. The descriptive analysis and binomial test were used to have an in-depth data analysis for specific questions. Generally, the binomial test is using for experimental research (Norušis, 2006). Further to him, the test help to select a possible outcome between the two outcomes. In addition, the test provides what the probability of favourable outcomes.

4. Results and Findings

4.1. Software usage in Sri Lankan construction firms.

Through the research findings it was identified that 76% of Sri Lankan construction companies utilize software applications namely as Microsoft office package, Autodesk Auto Cad and Microsoft project. Out of 3D supported software (AutoCAD, Revit, Sketchup, CostX) only two software support BIM and they were identified as Revit and CostX. The Revit has 5% of usage rate and CostX software has 6% which were considerably low. This emphasize that adoptability of BIM prevails in a basic stage. The usage of CostX software highlighted that 5D BIM related quantity take off is practicing in Sri Lankan construction industry and thus Sri Lankan construction industry might be in level 1 or level 2 in BIM maturity levels.

4.2. The approaches to overcome software issues

Different approaches were utilized to overcome issues related to software as search on internet, refer user manual, online forums, looking for vendor support and other methods. In here 62% of the respondents selected "*Search on internet*" as the first approach where "*Looking for vendor support*" were identified to be placed second with 29%. Further, binomial test was conducted for the most significant response of "search on internet" method and where the mode value of the distribution is 13 and relevant probability of the mean is 0.18 and is represented in Figure 1.

The cumulative all probabilities are equal to the area of the graph. The low probability of the mean value emphasizes where is high influence from the other factors which were consist of failure side.

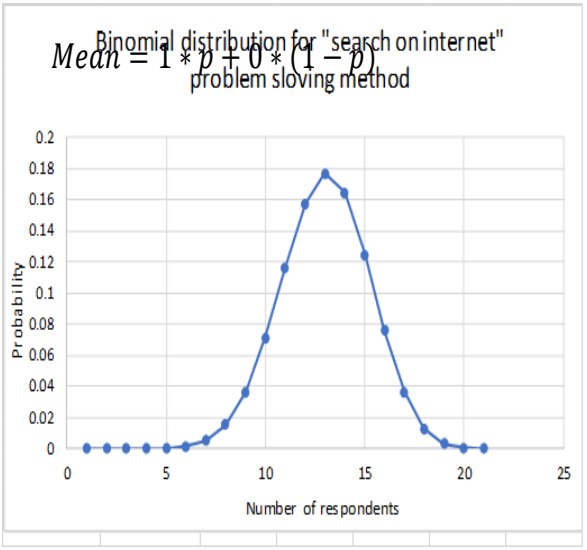

Figure 1: Binomial Distribution curve for "search on internet" approach

Mean value was derived as follows.

Where; p= Probability

$Mean = 1 * 0.62 + 0 * (1 - 0.62)$

$Mean = 0.62$

The variance was derived as follows.

$Variance = 21 * 0.62 * (1 - 0.62)$

Where; p= Probability,

n= sum of independent variables

$$Variance = np(1 - p)$$

$Variance = 4.94$

According to the mean, when increasing the respondent rate the selection of "search on internet" problem solving method will be reach to the 62%. In addition, variance is emphasizing the spread of probability distribution. When variance is increasing the maximum probability is dropping down which would change the bell shape of the curve.

4.3. Proprietary software and Free and Open Source software (FOSS) usage of Sri Lankan construction firms.

Error! Reference source not found. illustrates the usage of FOSS and propriety software in Sri Lankan construction industry. 85% of companies have adopted proprietary software and only 15% have adopted FOSS explicating that majority use proprietary software.

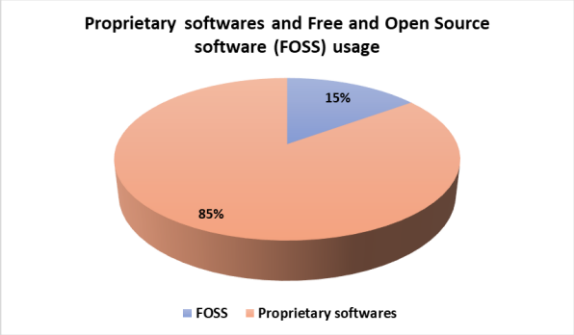

Figure 2: Proprietary software and Free and Open Source software (FOSS) usage

4.4. Minimize software cost considering low usage of software features

While identifying the acceptance of usage of software features in proprietary softwares. The proprietary software users require finances for software licenses and most of users were not using over 50% of their features. This is a capital wastage due to not fully utilizing the software. This must be minimized and thus encourage them to fully take the usage of FOSS.

Table 1: How to minimize software cost considering low usage of software features of software.

Respondent No	Key words	Priorities	
		Common key words	Qty
10	Open source software	Open source software	2
14	Manually	Manually	1
16	Cloud version	Cloud version	2
19	Product vision, Training	Product vision	1
20	Optimizing existing licenses, Understanding the need	Training	1
21	License duration, Number of licenses, Software requirements, Software clouds	Optimizing existing licenses	2
22	Both software types	Understanding the need	1
24	Optimum usage, Existing software	License duration	1
31	Experts advise	Number of licenses	1
33	High technical applications	Both software types	1
		Experts advise	1

According to the **Error! Reference source not found.** no significant method prevails to minimize the wastage of not using features of softwares. However, the result might be affected by the open source software awareness as there is low awareness rate for open source software in construction industry in Sri Lanka according to findings in section 4.5. Therefore, the response for open source software might be low. Two respondents mentioned that using software cloud the partially utilization of the software could be reduced but there is no major effect from the software cloud. Additionally, another two respondents mentioned optimizing existing licenses computers whereas one respondent identified that understanding the software need and selection of software has a considerable impact.

4.5. Awareness in open source software in the firms

This figure is based on all the employees with IT knowledge. 53% of respondents has 26%-50% of FOSS knowledge and 26% of them has 0%-25% FOSS knowledge. This is considerably less percentage and only 21% of respondents has 51%-75% of FOSS knowledge. There is no organization which has more than 75% of FOSS knowledge of employees. Thus it is required to have reasonable brains storming sessions for employees to gain knowledge of FOSS before the open BIM implementation.

4.6. Most suitable ways for open source software supporting methods in Sri Lanka

FOSS support required to Sri Lankan construction organizations is available in many methods such as online forums, purchase vendor support from third party company, support software by company itself and through the support of project sponsor. Accordingly, 45% of respondents selected taking support from online forums and 35% of respondents selected purchase vendor support from third party software company as the most suitable methods of supports. Accordingly, it is evident that the most appropriate choice is online forums and it is very cost effective and the satisfactory level is high with quick response time.

4.7. Difference between proprietary BIM vs openBIM features

100% respondents agreed that "*openBIM, easy to file sharing through the software and improving*

the coordination among employees". Only 65% agreed that "*open BIM can take necessary software improvements within the organization*". However, 70% of them stated that "*Both OpenBIM and proprietary BIM speed up the quantity takeoff by the same amount*" where 85% identified that "open BIM reduces overall project cost of the organization".

Furthermore, only 40% stated that "*Both provide more accurate design visualization*". These analyzed features were highly benefited to open BIM technology adoption in Sri Lankan construction industry.

4.8. Challenges to openBIM implementation in an organization

Accordingly, 35% respondents have problems with "*Lack of the knowledge about open BIM*", 5% of respondents have problems of "*Lack of high capacity computers*", 20% have problems with "*Lack of technical support*" and 40% of respondents have "*Lack of open BIM based projects*".

This explicit that majority have the problem of lack of open BIM based projects. This is a common problem for proprietary BIM implementation.

4.9. Remedies to overcome the interoperability issues with in Sri Lankan construction field

One of the major problems in BIM maturity Level 2 is interoperability issues between software. Accordingly, 60% of respondents experienced interoperability issues in Sri Lankan construction industry. As per Table 2, majority of respondents are using software packages to overcome the interoperability issues. However, this method is a costly solution and it causes some contractual issues. Consequently, when using software packages most of the participants of construction projects must use same set of software packages and some parties doesn't agree with that.

Although two respondents are using file converters to avoid interoperability problems it is not a successful method as it leads to data loses and file converter has legal issues to use publicly.

Moreover, looking forward to the help from IT section and other three answers belong to common data format. This solution is more applicable at the BIM level 3.

Table 2: Remedies which could be taken to overcome interoperability issues

Respondent No	Key words	Priorities	
		Common key words	Qty
10	File converters	File converters	2
15	Converting	Limit the interaction with Incompatible	1
16	Limit the interaction with Incompatible software	Software package	4
19	Similar version	Data exporting formats	1
24	Software packages	Help of IT section	2
30	Software package Types of data exporting formats	Common data format	1
31	Help of IT section		
32	Common data format		
34	IT experts,		
8	Software package		

4.10. Implementing openBIM in construction firms in Sri Lanka

Six respondents mentioned that lack of knowledge with openBIM, maybe a great barrier for implementing this technology as the openBIM knowledge of all participants of construction project impact to start an openBIM project. While five respondents stated high cost for making openBIM infrastructure is a barrier as it requires IT facilities, openBIM knowledge, openBIM adoption of other projects stakeholders and knowledge of standards openBIM protocols. Additionally, Open source software needs software maintenance and software upgrades for bug fixing and adding new features according to project requirements. Three respondents identified the requirement of good technical support before the openBIM implementation including computer hardware, proper communications, network facilities and server facilities. Lack of openBIM based projects were also a hindrance which leads to kept to the conventional construction process.

Training programs and BIM curriculum aid for the implementation of openBIM in Sri Lanka. BIM curriculum is a training facility which provide by the BIM software vendors illustrating the way to use the software and features of the software and

they must be launched for the adoption of openBIM.

Additionally, government responsibility for implementing openBIM is essential. It is evident that countries including Singapore and United Kingdom, their government made a rule to use BIM for all the construction which were above certain extend of construction value. These rules greatly support BIM adoption of a country.

5. Discussion and Conclusion

OpenBIM is a unique technology which is currently operating in construction industry and which can be developed to manufacturing industry. OpenBIM facilitates special characteristics for construction information management system. OpenBIM project stakeholders work with common data environment and all the information of the construction project are going through the centralized data model. The responsibility of data management in the model is holding by the information managers. Collaborative working environment could be built by using one software vendors' product or by exchanging data from the industry supported data exchanging format. All stakeholders including Civil Engineers, Quantity Surveyors, Project Managers, Clients must greatly adopt IT related technologies during the period of openBIM adoption, even though they have no proper IT related background. The cost embedded with the comport hardware, networking facilities and related technologies were considerably higher with openBIM related construction process comparing to conventional construction process. The uncommon professionals are contributing to construction project through the roles such as information managers and their duties and responsibilities which were embedded with profession is not familiar to existing professionals in the industry.

From the findings of the study, it can be concluded that openBIM is not yet practical in Sri Lanka. Potential for its adoption is very low in current context of the country. The key challenges can be divided into two categories as technical and industrial. Accordance with research findings technical challenges were associated with high cost to build up IT infrastructure for required level, low level of awareness of open source software and lack of training facility. The industrial challenges consisted with, resistance to change, lack of openBIM based projects, legal system not fully support with contractual agreements in openBIM, requirement of openBIM project governing regulatory body and systematic protocol for proper openBM adoption in Sri Lanka.

There was no clear evidence to deduce that these would be overcome. Although various approaches were highlighted to overcome challenges, there was no systematic approach. After considering all those factors, it can be concluded that the Sri Lankan construction industry is not yet ready for openBIM adoption.

Recommendations could be brought for the potential to adopt openBIM in Sri Lankan construction industry. Conducting proper educational programs and training sessions consisting of openBIM software and contractual procedures of openBIM context are among them.

The professional practitioners of construction industry require better knowledge about openBIM procedures therefore, as there are much more complexity comparing to conventional construction procedures. Working with fully collaborative working platform was different than the proprietary working platform where proprietary BIM users also must have separate training for openBIM adoption. Training sessions must be conducted in a much effective manner without any disturbance to regular work of organizations.

Conventional construction has systematic procedures to conduct the construction project and BIM has a protocol to conduct BIM based projects. The copyright rights and collaboration procedures are different to BIM projects when comparing with openBIM projects. Consequently, there is a requirement of systematic protocol for openBIM based projects or to have an update version of BIM protocol. There are different legal systems and different construction cultures in different countries thus, better to have a separate openBIM protocol for Sri Lanka and involvement of regulatory body for openBIM based projects is very supportive to implement systematic openBIM standards in Sri Lanka.

Government responsibility for openBIM implementation in Sri Lanka might be an appropriate remedy for start of an openBIM project.

BIM based projects save 20% to 30% of construction cost and it proved bunch of benefits during opening stage as well where in a large project the cost saving is considerably a large amount. When considering openBIM, the cost savings is greater than BIM based projects. Hence, government must establish a rule for major construction openBIM model and practice openBIM during construction stage and make it mandatory for projects which are above certain construction cost level. This will be more productive for openBIM adoption in Sri Lanka.

6. References

Aia, V. P. (2017). Building Information Modeling (BIM) Interoperability Issues, 1–21.

Aruna, K., Perera, C., & Weerawarne, S. (2013). Free and Open Source Software Technology Adoption in the Sri Lankan Banking Industry, 1(1), 20–34.

Autodesk. (2016). Improving Building Design Project Collaboration using openBIM ® Data Exchange Standards Industry Foundation Classes (IFC). Retrieved from https://damassets.autodesk.net/content/dam/autodesk/www/campaigns/interoperability/fy17-aec-ifc-interoperability-whitepaper-en.pdf

Azam, M., & Hussain, I. (2009). The Role of Interoperability in eHealth. Retrieved from http://www.engineering.com/BIM/ArticleID/12131/The?Role?of?Interoperability?in?BIM.aspx

Bank, C. (2015). Annual Report 2015. Retrieved from http://www.cbsl.gov.lk/pics_n_docs/10_pub/_docs/efr/annual_report/AR2015/English/content.htm

Bergeron, J. E., & Allott Moore, J. (2011). File processing of native file formats. Retrieved from https://www.google.com/patents/US20120265759

BIM Blog, (2017). Understanding Interoperability with BIM November, 5–7. Retrieved from http://www.bimhub.com/blog/understanding?interoperability?bim/

BIMhub. (2017). Advantages of Open BIM for AEC Companies. Retrieved from http://www.bimhub.com/blog/advantages?open?bim?aec?companies

Blog, (2017). BIM Interoperability - is the industry sailing under false colors ?, 1–13. Retrieved from http://blog.areo.io/bim-interoperability/

Breit, M., Vogel, M., Häubi, F., Märki, F., Soldati, M., Etesi, L. I., … Walther, A. (2008). Building Information Modelling Demystified: Does it Make Business Sense to Adopt Bim?, (2004)

Building Smart standards. (2008). Retrieved from http://www.buildingsmart-tech.org/

buildingSMART-Tech.org. (2018). Retrieved from http://www.buildingsmart-tech.org/specifications

Central Bank of Sri Lanka. 2009. CBSL Annual Report 2009: Economic Infrastructure. [Accessed 2018 Jan 13].

Cerovsek, T. (2011). A review and outlook for a “Building Information Model” (BIM): A multi-standpoint framework for technological development. Advanced Engineering Informatics, 25(2), 224–244. https://doi.org/10.1016/j.aei.2010.06.003

Eastman, C., Liston, K., Sacks, R., & Liston, K. (2008). BIM Handbook Paul Teicholz Rafael Sacks. https://doi.org/2007029306

Economides, N., & Katsamakas, E. (2006). Linux vs. Windows: A Comparison of Application and Platform Innovation Incentives for Open Source and Proprietary Software Platforms. The Economics of Open Source Software Development, 207–218.

Elvitigala, D. (2002). Analysis of free and open source software adoption in Sri Lankan software companies. Retrieved from http://dl.lib.mrt.ac.lk/bitstream/handle/123/12527/post-text.pdf?sequence=2&isAllowed=y

Excellence, C. (2012). Open BIM & Closed BIM. Retrieved from http://ckegroup.org/thinkbimblog/wp-content/uploads/2012/04/BIM-vs-OPENBIM.pdf

Fellows, R. and Liu, A., 2008, December. Impact of participants' values on construction sustainability. In Proceedings of the Institution of Civil Engineers-Engineering Sustainability (Vol. 161, No. 4, pp. 219-227). Thomas Telford Ltd.

Froese, T. (2003). Future directions for IFC-based interoperability. Electronic Journal of Information Technology in Construction.

Gallaher, M. P., O'Conor, A. C., Dettbarn, J. L., & Gilday, L. T. (2004). Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry. Nist, 1–210. https://doi.org/10.6028/NIST.GCR.04-867

Gallaher, M. P., O'Conor, A. C., Dettbarn, J. L., & Gilday, L. T. (2004). Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry. Nist, 1–210. https://doi.org/10.6028/NIST.GCR.04-867

Graphicsoft (2013). Retreived from http://www.graphisoft.com/archicad/start-edition/

Guzmán, E., & Zhu, Z. (2014). Interoperability between Building Design and Building Energy Analysis. Computing in Civil and Building Engineering (2014), 17–24. https://doi.org/10.1061/9780784413616.003

Hallberg, D., & Tarandi, V. (2011). On the use of open bim and 4d visualisation in a predictive life cycle management system for construction works. Journal of Information Technology in Construction (ITcon), 16, 445-466.

Hassanain, M. A., Froese, T. M., & Vanier, D. J. (2001). Development of a maintenance management model based on {IAI} standards. Artificial Intelligence in Engineering, 15(2), 177–193.

Hijazi, M.O., 2015. Bridging the gap: A tool to support bim data transparency for interoperability with building energy performance software. University of Southern California.

Hill, T., & Steele, R. (2014). ISO : Standards for BIM & Infrastructure ISO, a global system, (October).

Huovila, P., Hyvärinen, J., & Palos, S. (2014). Linking SBA metrics with construction products manufacturers' BIM e - Catalogues. Sustainable Building Alliance, (October).

Jayasena, H. S. (2015). Developemet of BIM. Retrieved from http://www.bimlab.net/bimacademy-home/21-development-of-bim.html

Jayasena, H.S., & Weddikkara, C. (2013). Assessing the BIM Maturity in a BIM Infant Industry. In: The Second World Construction Symposium 2013: Socio-Economic Sustainability in Construction, Sri Lanka, 14 – 15 June 2013. Colombo, Ceylon Institute of Builders, 62-69.

Jelle, B. P. (2013). 7 Th Nordic Conference on Construction Economics and Organisation 2013. The Role of Accelerated Climate Ageing of Building Materials, Components and Structures in the Laboratory, (June), 92.

Johnson, R.B., Onwuegbuzie, A.J. and Turner, L.A., 2007. Toward a definition of mixed methods research. Journal of mixed methods research, 1(2), pp.112-133.

Juan, D., & Zheng, Q. (2014). Cloud and Open BIM-Based Building Information Interoperability Research. Journal of Service Science and Management, (April), 47–56. https://doi.org/10.4236/jssm.2014.72005

Liebich, T., & Wix, J. (1999). IFC Specifications Development Guide. International Alliance Of Interoperability, 129.

Lipman, R. R. (2011). SteelVis (aka CIS/2 Viewer).

McGraw Hill Construction. (2012). The Business Value of BIM in North America. SmartMarket Report.

Merschbrock, C. (2014). Succeeding with Building Information Modeling : A Case Study of BIM Diffusion in a Healthcare Construction Project. Retrieved from https://doi.org/10.1109/HICSS.2014.490

Motawa, I., & Almarshad, A. (2013). A knowledge-based BIM system for building maintenance. Automation in Construction, 29, 173–182. https://doi.org/10.1016/j.autcon.2012.09.008

National BIM Standard-United States. (2016). Frequently asked questions about the national BIM standard-United States™. Retrieved from https://www.nationalbimstandard.org/faqs

Neuman, W.L. (2011), Social Research Methods: Qualitative and Quantitative Approaches, 7th edn, Pearson/Allyn and Bacon, Boston

Nisbet, N., & Liebich, T. (2007). ifcXML Implementation Guide. History, 1–50.

Nitithamyong, P., & Skibniewski, M. J. (2004). Web-based construction project management systems: how to make them successful?. Automation in construction, 13(4), 491-506.

Norušis, M. J. (2006). SPSS 14.0 guide to data analysis. Upper Saddle River, NJ: Prentice Hall.

Panuwatwanich, K., Wong, M. L., Doh, J.-H., Stewart, R. A., & McCarthy, T. J. (2013). Integrating building information modelling (BIM) into Engineering education: an exploratory study of industry perceptions using social network data. Australasian Association for Engineering Education Conference (AAEE2013), 1–9. Retrieved from http://ro.uow.edu.au/cgi/viewcontent.cgi?article=2929&context=eispapers

Rousset, F. (2008). GENEPOP'007: A complete re-implementation of the GENEPOP software for Windows and Linux. Molecular Ecology Resources, 8(1), 103–106. https://doi.org/10.1111/j.1471-8286.2007.01931.x

Teddlie, C. and Tashakkori, A., 2003. Major issues and controveries inthe use of mixed methods in the social and behvioral sciences. Handbook of mixed methods in social & behavioral research, pp.3-50

Van den Helm, P., Böhms, M., & van Berlo, L. (2010). IFC-based clash detection for the open-source BIMserver. Computing in Civil and Building Engineering, Proceedings of the International Conference. Nottingham University Press, Nottingham, UK, 30, 181.

Weerasinghe, K.B. and Ekanayake, L.L., 2013. Technology transfer to local construction industry through foreign contractors: barriers and enablers.

Westbrook, L. (1994). Qualitative research methods: A review of major stages, data analysis techniques, and quality controls. Library & Information Science Research, 16(3), 241-254. doi:10.1016/0740-8188(94)90026-4

WSO2 Coperation. (2017). The WSO2 Advantage.

Yang, Q. Z., & Zhang, Y. (2006). Semantic interoperability in building design: Methods and tools. CAD Computer Aided Design, 38(10), 1099–1112. https://doi.org/10.1016/j.cad.2006.06.003

Zhi, H. (1995). Risk management for overseas construction projects. International Journal of Project Management, 13(4), 231–237. https://doi.org/10.1016/0263-7863(95)00015-I

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